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Electron detachment cross sections of negative ions

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Electron detachment cross sections of some negative ions are calculated semi-empirically. The results are in fairly good agreement with the available experimental data provided Coulomb effect is taken into account.

1. INTRODUCTION

Inelastic cross sections are of importance in many branches of physics such as astrophysics, plasma physics etc Exact quantum mechanical calculations are possible only for the particular case of atomic hydrogen For other targets use of approximate methods becomes necessary (Rudge 1968)

Miller & Platzman (1957) proposed an alternative approach to calculate inelastic cross sections for incident energies great enough to ensure validity of the Born-approximation. Vriens (1965) extended this approach to the low energy region semiempirically. He obtained encouraging results for atoms and molecules Since then the approach has been applied to positive ions with satisfactory results (Chandra & Narain 1974). Hence it is of interest to apply the same approach to obtain the electron detachment cross sections of negative ions, viz , H^-, Li^-, Na^- and K^- Inclusion of Coulomb repulsion improves the results significantly, particularly in the low energy region

2 THEORY AND METHOD

Following Vriens (1965) the cross section for electron detachment is given by

$$Q_u = AF \, \frac{E-I}{E^2} \ln\{1+C(E-I)\}. \qquad \ldots \quad (1)$$

Here E is the incident electron energy, I, the electron affinity of the target and C is a collision parameter (Inokuti 1971). F is a function whose value for negative ions is very nearly equal to unity. A is proportional to M_i^2 which is expressible in terms of the differential oscillator strength $df/d\epsilon$ as

$$M_i^2 = \int_0^\infty \frac{R}{I+\epsilon} \frac{df}{d\epsilon} \, d\epsilon$$

where ϵ is the energy of the ejected electron. Other symbols have their usual meanings (Vriens 1965)

The inclusion of the Coulomb repulsion is effected through the equation (Geltman 1960)

$$Q_c = \left(1-\frac{2\sqrt{\pi}}{E\sqrt{Q_u}}\right) Q_u, \quad \ldots \quad (3)$$

where Q_c and Q_u are the cross sections with and without Coulomb correction in πa_0^2 and E is the incident electron energy in rydbergs

For each target we plotted $\frac{R}{I+\epsilon} \cdot \frac{df}{d\epsilon}$ vs ϵ, and obtained M_i^2 by graphical integration. The value of M_i^2 for H^- obtained in this way agrees with that of Inokuti & Kim (1968) within 7% on using the oscillator strength data of Geltman (1962) We have used the data of Moores & Norcross (1973) and Norcross & Moores (1973) for other ions.

Table 1

Target	I (eV)	C (eV^{-1})	M_i^2
H^-	0 7500	2.16	7.00
Li^-	0.6163	2.59	17.80
Na^-	0.5388	2.88	20.60
K^-	0 4721	3.66	27.72

The parameter C for H^- is determined using the experimental data of Peart *et al* (1970) in the manner indicated by Vriens (1965) at an energy near 200 times threshold where Born and Bethe-Born approximations are valid Since the experimental data are not available for other ions the Coulomb-Bethe-Born cross sections are used for them (John & Williams 1973) Various parameters used in the present calculations are displayed in table 1

2. Results and Discussion

The electron detachment cross sections calculated using eqs. (1) and (3) are exhibited in table 2 for Li^-, N_a^- and K

In figure 1 we have compared our results (corrected and uncorrected) for H^- with other experimental data (Dance *et al* 1967, Peart *et al* 1970) The experimental data of Tisone & Branscomb (1966) do not exhibit proper asymptotic behaviour, but they agree well with those of Dance *et al* (1967) below 60 eV (Kim & Inokuti 1971).

Table 2. Electron detachment cross sections of Li^-, Na^- and K^- in units of 10^{-16} cm²

Incident electron energy (eV)	Li^-	Na^-	K^-
2.72	84.42	162.47	371.85
5.44	197.40	262.68	435.76
8.16	19[illegible].11	246.69	386.56
10.88	178.27	222.11	339.22
13.60	162.38	200.37	301.39
27.21	110.74	133.76	195.09
54.42	69.23	82.65	118.38
108.84	41.12	48.78	69.08
217.68	23.68	27.97	39.29
326.52	16.97	20.00	28.00
489.78	12.08	14.23	19.85
734.66	8.56	10.07	14.02
979.55	6.69	7.86	10.93

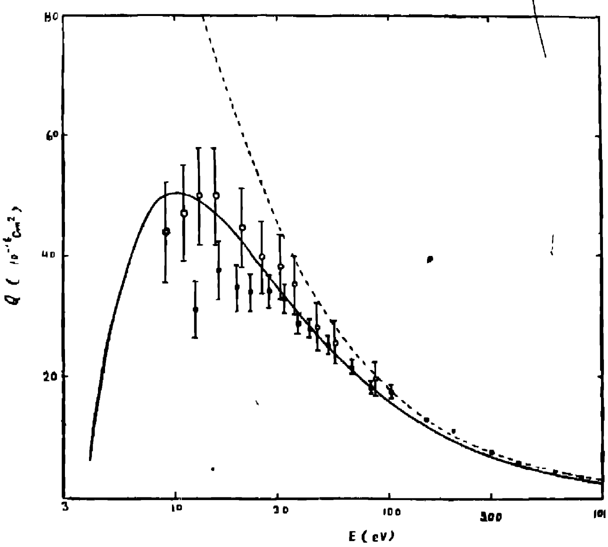

Fig. 1 Cross sections for the reaction $H^- + e \rightarrow H + 2e$
——, present results (Q_c); - - - -, present results (Q_u). Experimental data: ●, Peart *et al.*, O, Dance *et al.* Typical error limits are given for the experimental data

It is obvious from the figure that our uncorrected results overestimate the experimental cross sections below 60 eV whereas the corrected results compare favourably with the experimental results of Dance *et al* (1967) throughout the energy region considered. It may be noted that below 30 eV the two sets of experimental data do not agree with each other Also below this limit the Coulomb correction itself becomes questionable because the electron trajectory no longer remains classical as assumed in the derivation of formula (3) Hence, no definite conclusion below this energy limit could be drawn However, above this limit our corrected cross sections should be fairly accurate.

It would be worthwhile to remark about some other theoretical results also. The calculations of McDowell & Williamson (1963) for H^- agree closely above 20 eV with the experimental results of Dance *et al* (1967) but overestimate them below this limit The calculations (BS 2) of Bely & Schwartz (1969) agree nicely with the experimental results of Peart *et al* (1970) (see figure 10 of their paper) throughout the whole energy range considered The calculations of John & Williams (1973) are of the same accuracy as more elaborate calculations of Bely and Schwartz.

It may be concluded that the Vriens' approach is satisfactory for negative ions also provided, of course, the Coulomb effect is taken into consideration

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